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The Relation of the Sensory Reactions to the Assembling Habits of Hippodamia convergens.

A thesis submitted in partial satisfaction of the requirements
for the degree of

Master of Science

at the University of California

By

Martha Stillmannette Beaser.

UNIV. OF
CALIFORNIA

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UNIV. OF
CALIFORNIA

THE RELATION OF SENSORY REACTIONS TO THE ASSEMBLING HABITS OF HIPPODAMIA CONVERGENS.

Introduction.

The assembling habits of the lady-bird beetles (Coccinellidae) have been observed and referred to for many years but no scientific experimentation to ascertain the causes of this characteristic habit so peculiarly illustrated by Hippodamia convergens has, to the writer's knowledge, been undertaken previous to this.

The observations and experiments herein described have been carried on under the direction of Professor W. B. Herms in the Parasitological Laboratory of the University of California.

The earliest historical record, to the writer's knowledge, referring to the assembling habit of the Coccinellid beetles is found in Kirby and Spence's Entomology (1856) in which an account is given of the terror caused to the inhabitants of one"of the principle towns of Berkshire" thinking the great assembling of the insects boded some evil, "the authorities .... in October, 1835, according to the Reading Mercury, having had a most formidable invasion of this beautiful insect (ladybird) .... the parish engines, as well as private ones, were called into requisition with tobacco fumigated water to attach and disperse them. Kirby and Spence explain the interesting behavior of these little insects as follows:

"The ladybirds (Coccinellae) seem to pursue the Aphids; for I know no other

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reason to assign for the vast number that are sometimes, especially in the autumn, to be met with on the sea coast, or on the banks of large rivers. Many years ago, those of the Hamber were so thickly strewed with the common ladybird (C. septempuctata) that it was difficult to avoid treading upon them. Some years afterward I noticed a mixture of species, collected in vast numbers on the sand hills at the sea shore at the northwest extremity of Norfolk. My friend, the Rev. Peter Lathbury, made long since a similar observation at Arford on the Suffolk Coasts; and about five or six years ago (1854-5) they covesed the cliffs, as I have before remarked of all the watering places on the Kentish and Sussex coasts, - to the no small alarm of the superstitious,"............These last (the ladybirds) probably emigrated with the aphids from the hop grounds" ...."Whether the latter and their devourers cross the sea has not been ascertained; that the Coccinellas attempt it is evident from their alighting upon ships at sea as I have witnessed myself."

No other record of an endeavor to account for the assembling habits of the Coccinellids, seems to have been made until that of Carnes (1912) based on field observations on Hippodamia convergens.

Economic.

Hippodamia convergens has come to be recognized as of considerable economic significance. Kirby and Spence (1860) believed they "followed the aphids from the hop fields" and Riley (1881) in his report as Entomologist remarks upon the scale infested trees of California being found swarming with a natural enemy "many species of ladybird ". We find also many who misunderstand the relations of the ladybird to the aphid, laying at the door of the former the depredations of the latter. Even as late as 1891 Weed, of Mississippi, reports finding Hippodamia convergens feeding upon leaves of the cabbage and that "they were poi-

soned with Paris Green". Howard (1895) reports that in Corvallis, Oregon, Hippodamia convergens was seen " feeding on the leaves of the sugar beet and canaigre". Webster (1903) in giving results of some breeding experiments on different species of Hippodamia in Massachusetts tells also of the reported finding of a new insect parasite(?) on the cotton in Georgia which turned out to be Hippodamia convergens and as he remarks the ladybird probably checked an outbreak of the cotton aphis at that time.

The importance of the ladybird as a natural check to the spread of aphids is recognized by the California Horticultural Commission and in consequence millions of these insects are collected in the Sierra Nevada mountains by the Superintendent of the State Insectary and are sent to the Imperial Valley and elsewhere to be used in controlling the aphids of the cantaloupe and other crops.

The experiments recorded in this paper were undertaken with the express purpose of getting some definite data upon the sensory reactions of Hippodamia convergens and their relation to the assembling habit. This includes both laboratory and field experimentation and observation.

Field Observations.

The field observations by the writer covered a period from September to the middle of December, 1912, and the middle of January to the first of April, 1913. The observations were principally made in Berkeley, California and vicinity. When first observed in the early weeks in September the insects were flying about freely and mating, but beginning with the first week in October they were observed to be collecting in small numbers in comparatively sheltered places under leaves, and the like, away from the direct rays of the sun but in warm, dry places.

As winter came on and the temperature was lower the insects collected in larger bunches and when disturbed crawled about in a sluggish manner adding them-

selves to other bunches near them or returning to their former place.

With the first warm days in February they again started to move about and mate. At this time numbers were collected and an endeavor was made to rear them. The females began depositing eggs at this time.

There are two large and well known colonies of Hippodamia convergens in the vicinity of Berkeley, one in Little Saw Mill Creek, Contra Costa County and the other near Lagunitas, Marin County.

A visit to one of these colonies reveals a truely remarkable sight. In early February when the writer visited the former colony the insects had started to disperse in their search for food and were mating but there were still literally hundreds of thousands of these insects.

The favorite place of hibernation is a sunny well drained spot near a running stream. The decaying roots or limbs of a dead tree seems a favorite central point, - they crawl among the loose leaves and dry grass on the ground until it is infested several inches deep and all the low shrubbery about the place is actually bent-down with the weight of the insects. Every twig and dry stem had its characteristic mass at the tip, that is, the insects being negatively geotropic crawl to the top of whatever they are on and then either fly away or cling in this position.

An observer remarked to the writer that he had watched the colony for many seasons and that in late September when the ladybirds were returning to hibernate the air was often so full of the flying insects that passers-by were forced to beat them off with their hats to prevent the insects from clustering on them by thousands.

Odor.

The ladybird beetles have a very characteristic odor and a number of experi-

ments were performed to ascertain their reactions, if any, to odors of different sorts one of the theories offered by Carnes (1912) and others for their assembling habits was that of odor attraction. The writer believes this to be protective rather than anything else as this strong odor proves distasteful to birds and other enemies of insects.

The following experiments were employed to determine the possible relation of odor to the assembling habit. While the value of these experiments would be greater if they had been carried farther, the immediate results did not seem to warrant more time being given to so apparently fruitless an end.

Series I. Use of crushed ladybirds.

Experiment 1-, A small handful of insects was crushed in a small vessel and the resultant liquid placed as a smear in sterilized watch glasses. The characteristic odor was unmistakable. These watch glasses were placed in the fields where there were many ladybirds but with the result that the insects were not attracted.

Experiment 2 -, A glass stopper was smeared with liquid from crushed ladybirds and placed on the wire of a cage containing insects. Although the odor was strong the insects within the cage acted quite indifferent to it.

Experiment 3 - , Wire cages containing insects were placed in the field. Other ladybirds in the field were not attracted to those in the cages.

Series II. Use of artificial odors.

Experiment 1 -, A slide with Canada Balsam upon it was placed in a long net covered box. Fifty insects were liberated in the box and their behavior observed. They seemed quite indifferent to it. They avoided the sticky material but did not seem either attracted or repelled by the odor.

Experiment 3,- The above was repeated with oil of turpentine and

oil of cedar with similar results.

The results of experimentation upon Hippodamia convergens and its reaction to odor leads to the conclusion that while, without doubt, odor has much to do in sex attraction and as a protection from enemies, it has little or nothing to do with the assembling habit.

Light.

The reactions of Hippodamia convergens to light are very interesting and very definite in their results. The reactions are always of a positive nature.

The experiments with regard to light reactions were carried on in the physiological dark room and may be divided into two classes, - one involving masses of the insects to secure group reactions and the other involving individuals.

Series I. Group reactions.

Experiment 1 - , Approximately five hundred ladybirds were liberated on a black table ($3\frac{1}{2}$ x 7 ft.) in the dark room under a light intensity averaging 7.5 C.M. When first liberated the insects ran about aimlessly for a few moments and then started in a more or less direct line for the light and at the end of an hour were, with the exception of a few individuals which had fallen over the edge of the table in the first running about, collected about the electric light bulb, some crawling excitedly about on the bulb (partly a heat reaction) and the greater number assembling in the region of more subdued light of the shadows at the base of the globe.

Experiment 2 -, Two hundred insects were liberated in a glass box on a table in the dark room, the light was the same as in the above experiment (7.5 C.M.) After an interval of an hour the insects were assembled on the sides of the box nearest the light but where they were sheltered from the direct rays

of the light.

Experiment 3 -, One hundred insects were liberated at one metre distance from a light averaging 1.52 C.M. At the end of thirty minutes, ninety-six were collected around the light, three did not react and one very slowly.

Experiment 4 -, One hundred insects were liberated at one metre distance from a light averaging 7.4 C.M. and at the end of thirty minutes ninety-seven were collected around the light, three did not react.

Experiment 5, - One thousand insects were strewn broad cast about the dark room within the area of a half circle from 10 ft.to 25 ft. distant from a single incandescent lamp resting upon a table (3 ft. high by 3 ft. 6 in. by 6 ft. 6 in.) no lady bird was closer than 10 ft. to the light. The insects started immediately to travel toward the table and at the end of fifteen minutes many were at the foot of the table, 45 minutes later, - an hour from the start, two insects were on the table 12 inches from the light, six were on the cord of the drop light leading to the light.

Unfortunately the floor of the physiological laboratory is of cement and the fine cement-dust collecting upon their bodies so impeded the efforts of the insects that they were unable to reach their goal and died on the way thus defeating the definite results of the experiment though not its ultimate object as there could be no doubt as to their positive reaction and the strength of the stimulus shown in their heroic efforts to react under such, to them, tremendous difficulties.

Series II. Reaction of individuals to light.

The experiments were again made in the physiological dark room, an equal number of males and females were used and the results tabulated. Two incandescent lamps were used whose intensities averaged respectively 1.52 C.M., 7.5 C.M

and both together 9.02 C.M. and each individual placed one metre distant from the light in each case. The average time that it took an individual to traverse the one metre distance to the 1.52 light was 1 min. 19 sec. ; to the 7.5 C.M. light, 1 min. 41 sec. and to the 9.02 C.M. light, 1 min. 35 Sec., slightly less time than for the medium light. They appeared to react with more steadiness to the lower intensities, becoming more erratic in the higher intensities, running about rather wildly at first before starting directly toward the light.

Summary of Photic Reactions.

The reactions of Hippodamia convergens to light are shown to be positive by the above experiments. There is however, little evidence here to show that light reaction is an important factor in causing the ladybirds to assemble, though it may be a contributing factor.

Heat.

The experiments upon Hippodamia convergens in relation to thermal stimuli were performed in the physiological dark room under known light intensities to eliminate, if possible, all other factors except heat and light.

The apparatus used was adapted after Fielde (1904) in her experiments on the heat reactions of ants. It consisted of a half cylinder of sheet copper (4.5 ft. long) The central portion (metre in length) was lined with filtre-paper extended over the edges and was held in place on the outside by paste. The ends were stuffed with cotton to prevent escape of insects and on the top were placed glass slides. These could be lifted to insert the thermometer, or place and replace the insects at any given point along the length of the tube and at the same time made it possible to see what was going on in the half cylinder. When complete darkness was desired blotters were placed over the slides to shut out the light. Using this apparatus a series of experiments were

undertaken to find out the reaction to heat through a range of temperature and also to discover, if possible, the optimum temperature of Hippodamia convergens and its reactions to extreme heat and extreme cold.

One end of the copper half cylinder was placed in ice and the other in a steam bath. The first was accomplished by hollowing out a cake of ice in which the half cylinder was placed and the broken ice carefully packed around it. The steam bath was prepared by placing a pan of water on an electric stove under the opposite end of the cylinder and placing over both a hood to hold the steam. The range of temperature was about twenty degrees, from 28° to 32° C. at the heated end to about 80° C. at the cold.

The results of a series of experiments on five hundred insects undertaken on alternate days for a period of two weeks were as follows:- The insects (100 at a time) were placed in the center of the cylinder, the temperature at one end being 80° C. and at the other 28° C. at the beginning of the experiment, - they were examined at the end of an hour and again at the end of two hours. Out of five experiments 94% of the insects were found collected at the heated end of the tube (temp. 26-28° C.) and at the end of the hour the temperature having risen from 28° C. to 32° C they had moved away in a mass from the hotter end to a point where the temperature was about 28° C., this being evidently their optimum temperature.

When the heat was intensified by the application of gas flame to the end of the metal half cylinder the insects were apparently attracted by the heat, but as it grew hotter flew around excitedly and very quickly succumbed, and in no case revived.

Their reaction to cold was equally rapid. When placed upon ice they immediately became completely dormant, giving the appearance of death, but upon

removal from the ice and warming and drying they were quickly revived. Even those left on the ice over twenty-four hours recovered in a few minutes when removed to a more favorable temperature. The reactions of Hippodamia convergens to thermal stimuli is evidently one of the most important we have to consider in relation to the assembling habit.

Summary and Conclusions.

1. The assembling habits of the Coccinellid beetles were known and commented upon as early as 1835, the feeding habit being given as a probable cause though this phenomenon seemed to be of a migratory rather than of an assembling nature.

2. The reason assigned may very well be the cause in this case as the search for food is probably one of the chief causes of migration, though no doubt there are also other factors. However the reaction we are discussing takes place after the feeding period is over and during the time when the food is least abundant in the places chosen for hibernation, particularly where the greatest numbers are then found, that is, in the winter months. Carnes (1911) describes the spot commonly chosen for hibernation as a "Topographical funnel" whose apex rests just below the summit of the Sierras and is the spot where the beetles collect year after year to spend the winter. The reaction caused by hunger and manifested in a search for food might cause a migration of the insects during the feeding season, but would not cause them to migrate year after year to a spot where no food exists. The cause must be sought elsewhere.

3. Carnes (1911) suggests that the characteristic odor of the insects plays a large part in their tendency to collect in the same spot for so many succeeding seasons. They do not react either in the field or in the laboratory to their own odor or to artificial odors so that odor seems to play no part other

than that of protection and, without doubt, in sexual attraction.

4. The reactions to light are positive, but the light stimulation seems to cause an increased movement and a reaction causing dispersal rather than assembling.

5. The reactions to heat seem to me to offer the most fertile field for further investigation. While not wholly responsible for the assembling habit the thermal reactions exert a powerful influence as evidenced by the fact that the beetles assembled both in the field and in the laboratory in small and increasingly larger groups as the temperature is lowered and disperse again as the temperature is raised. The temperature at which the Hippodamia convergens is caused to assemble is 28°C. .

6. That they collect year after year in the same place is largely due, no doubt, to the reactions to local conditions of climate, topography and prevailing wind currents, combined with their reactions to temperature with the changing seasons.

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